Phase Transport on Manifolds: A Cross-Domain Structure in Distributed Routing Systems

Abstract

This document presents an observation that distributed routing systems exhibit a common latent geometry organizing position as a two-dimensional manifold, decoupled from uncertainty managed in layered information regimes. The structure appears to emerge from operational constraints rather than theoretical design. Maritime navigation and network routing provide illustrative examples. The work is descriptive and exploratory.

1. Introduction

Operational systems frequently separate geometric position from uncertainty. This suggests a structural pattern: a manifold governing position, coupled with layers handling uncertainty. This note describes that pattern without claiming novelty in underlying mathematics.

2. Maritime Instantiation

The WGS84 ellipsoid provides a geometric reference surface with metric properties. Depth, tides, and local conditions are handled separately as statistical layers. This separation is not merely practical—it reflects a structural decoupling between geometry and uncertainty.

3. Information Regimes

System information appears to cluster into three regimes: low-entropy baseline (stable shared structure), mid-entropy propagated state (updates and forecasts), and high-entropy measurements (real-time signals). These regimes differ in stability and propagation behavior.

4. Cross-Domain Correspondence

Similar structures appear in network routing systems, where topology provides a stable underlying structure, routing updates propagate state, and real-time measurements influence decisions. Both systems operate under incomplete information and converge toward similar organization.

5. Case Study: Disruption

Under disruption, routing systems exhibit breakdown of stable structure and increased reliance on high-entropy signals. Shipping reroutes, delays, and cost increases illustrate how systems behave when structural assumptions fail.

6. Phase Inversion

When high-entropy inputs dominate decision-making, the system undergoes a phase inversion. Routing shifts from structured optimization to reactive behavior, driven by uncertainty rather than geometry.

7. Economic Consequences

Disruption leads to increased distances, fuel costs, insurance premiums, and delays. These effects are consistent with operation outside an optimal manifold, where efficiency degrades under uncertainty.

8. Interpretation

The observed behavior suggests that system efficiency depends on maintaining separation between structure and uncertainty. When this separation collapses, costs increase and predictability decreases.

9. Conclusion

This note documents a recurring structural pattern across domains. The observation is offered without prescription. The structure appears to emerge naturally in systems operating under constraint.